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ENVIRONMENTAL MONITORING AT A MARINE SEWAGE OUTFALL IN THE STRAIT OF GEORGIA, NEAR CAPE LAZO, BRITISH COLUMBIA

Regional Program Report: 84-23

By

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ABSTRACT

The Environmental Protection Service (EPS) monitored the Strait of Georgia off Cape Lazo in June 1984 to provide information on the impact of the recently installed Comox-Strathcona regional sewage outfall.

The only water quality parameter which changed due to the outfall was an increase in the ammonia concentration at depths of 25 m or more. However, the maximum ammonia value sampled (0.023 mg/l), is 1000-times less than the un-ionized ammonia concentration which is hazardous to marine life (Clark 1980).

Sediment particle size distribution was not affected by the outfall. Although sediment total volatile residue values increased between 1979 and 1984 (10-17 mg/g to 21.6-44.6 mg/g), it is not possible to conclude that the increase was due solely to the outfall, because sediments were sampled in late spring (1984) and mid-autumn (1979). Hence a seasonal influence cannot be excluded. Bacterial levels in sediments from two stations near the outfall showed low-level fecal contamination (50-70 MPN/100 g sediment), while levels at all other stations were at or below the detection limit (< 20-< 30 MPN). Sediment metal concentrations fall within the range of values observed at other Strait of Georgia locations.

Results of the 1984 survey are compared with results obtained during a 1979 EPS survey of the area by Holman et al. 1981. Fifteen stations were sampled in 1984 to obtain sediments for particle size, organic carbon, oil and grease, trace metal and bacteriological analyses. Water samples were taken at three stations near the outfall for nutrients (nitrite, nitrate, ammonia, and total phosphate) and dissolved oxygen analyses. Conductivity, temperature, and depth (CTD) profiles were taken at two stations to provide information on the salinity and density characteristics of the water column.

The area around the outfall will require continued monitoring in future years since the Strait of Georgia in this area supports diverse fisheries stocks (herring, groundfish, salmon, bivalves, geoducks, sea urchins).

RÉSUMÉ

En juin 1984, le service de la protection de l'environnement (SPE) a étudié les eaux du détroit de Georgia au large du Cape Lazo pour fournir de l'information sur l'impact des eaux usées déchargées par l'émissaire marin installé récemment par le district régional de Comox-Strathcona.

Le seul paramètre de la qualité de l'eau qui a changé dû à l'émissaire fut une augmentation de la concentration de l'ammoniac à des profondeurs de 25 metres ou plus. Cependant, la valeur maximale d'ammoniac échantillonnée (0.023 mg/l), est 1000 fois moins que la concentration d'ammoniac non-ionizée qui pose un risque à la vie marine (Clark 1980).

La distribution de la dimension des particules dans les sédiments ne fut pas affectée par l'émissaire. Même si les valeurs du résidu total volatil dans les sédiments out augmenté entre 1979 et 1984 (10-17 mg/g à 21.6-44.6 mg/g), on ne peut pas conclure que l'augmentation est due uniquement à l'émissaire parce que les sédiments furent échantillonnés vers la fin du printemps (1984) et au milieu de l'automne (1979); d'où une influence des saisons ne peut pas être exclue. Les niveaux de bactéries dans les sédiments de deux stations près de l'émissaire ont montré un bas niveau de contamination fécale (50-70 NPP/100 g de sédiment), alors que les niveaux à toutes les autres stations étaient égaux ou sous la limite de détection (20- 30 NPP). Les concentrations de métal dans les sédiments se situent dans les limites des valeurs observées à d'autres locations du détroit de Georgia.

Les résultats de l'étude de 1984 sont comparés avec les résultats obtenus lors de l'étude du SPE de la région en 1979 par Holman et al. 1981. Quinze stations furent échantillonnées en 1984 pour obtenir des sédiments pour analyses de dimension de particules, de carbone organique, d'huile et de graisse, de métal à l'état de trace et de bactéries. Des échantillons d'eau furent pris à trois stations près de l'émissaire pour des analyses de matières nutritives (nitrite, nitrate, ammoniac et phosphate total) et d'oxygène dissous. Les profils de conductivité, température et profondeur (CTP) furent mesurés à deux stations pour fournir de l'information sur les caractéristiques de la salinité et densité de la colonne d'eau.

La région autour de l'émissaire exigera un contrôle continu dans les années futures puisque le détroit de Georgia supporte des réserves de différentes pêcheries (hareng, poisson de fond, saumon, bivalves, panopes géantes, oursins) à cet endroit.

TABLE OF CONTENTS

		Page
ABSTRACT		i
RÉSUMÉ		ii
TABLE OF CONTENTS		iii
	List of Figures	v
	List of Tables	vi
1	INTRODUCTION	1
1.1	Study Area	2
1.1.1	Fisheries Resources	2
1.1.2	Oceanography	4
1.1.3	Benthos	4
1.1.4	Pollution	4
2	METHODS	7
2.1	Survey Area	7
2.2	Sediment Samples	7
2.3	Water Samples	7
2.4	Data	8
3	RESULTS AND DISCUSSION	9
3.1	Seawater Characteristics	9
3.1.1	Temperature, Salinity and Density	9
3.1.2	Dissolved Oxygen	9
3.1.3	Nutrients	11
3.2	Sediment Characteristics	11
3.2.1	Particle Size	11
3.2.2	Organic Carbon	14

TABLE OF CONTENTS (Continued)

		Page
3.2.3	Oil and Grease	14
3.2.4	Bacteriology	15
3.2.5	Metal Concentrations	18
3.3	Summary	22
REFERENCES		24
ACKNOWLEDGEMENTS		29
APPENDIX I	CTD DATA 11 JUNE 84 STATIONS CO-3 and CO-5	30
APPENDIX II	SEDIMENT PARTICLE SIZE DISTRIBUTION (%) STATIONS CO 1-20/84	33
APPENDIX III	SEDIMENT DATA 1979 AND 1984	35
APPENDIX IV	SEDIMENT FIELD REPLICATE AND LAB DUPLICATE DATA 1984	38
APPENDIX V	CORRELATION MATRIX SEDIMENT DATA 1984	41

LIST OF FIGURES

Figure		Page
1	SURVEY AREA: 6 NOV 79 AND 11 JUNE 84	3
2	CTD PROFILES STATIONS CO-3 AND CO-5 ON 11 JUNE 84	10
3	LOCATION OF MAXIMUM SEDIMENT METAL VALUES IN 1979 AND 1984	19

LIST OF TABLES

Table		Page
1	LIST OF SAMPLING STATIONS, DEPTHS, LOCATIONS AND SAMPLES TAKEN ON 11 JUNE 84	6
2	STATIONS CO-3, CO-5: DEPTH, TEMPERATURE, SALINITY, OXYGEN CONCENTRATION AND PERCENT SATURATION ON 11 JUNE 1984	9
3	STATIONS CO-3, CO-4, CO-5: NUTRIENT DATA 1984	12
4	SEDIMENT PARTICLE SIZE CHARACTERISTICS FOR STATIONS CO1-20/84	13
5	CORRELATION MATRIX: % SILT AND CLAY, T.V.R., OIL AND GREASE, DEPTH, DISTANCE TO OUTFALL (rank), DISTANCE (metres)	15
6	OIL AND GREASE AND TOTAL VOLATILE RESIDUE VALUES FOR STATIONS CO1-10/79 AND CO1-20/84	16
7	SEDIMENT FECAL COLIFORM DATA 1984	17
8	MEAN SEDIMENT METAL CONCENTRATIONS (mg/kg, dry wt.) AT STATIONS CO1-10, 1979/84	17
9	STATION LOCATION OF MAXIMUM AND MINIMUM DATA VALUES AND DISTANCE TO OUTFALL FOR SEDIMENT METALS 1979 AND 1984	20

LIST OF TABLES (Continued)

Table		Page
10	MULTIPLE REGRESSION AND CORRELATION COEFFICIENTS FOR 1984 SEDIMENT METAL CONCENTRATIONS AND DISTANCE FROM THE OUTFALL, DEPTH, AND % SILT AND CLAY (Stations C01-20/84)	21
11	SEDIMENT METALS: MEAN VALUES OR RANGE IN MEAN VALUES OF SELECTED STATIONS IN THE STRAIT OF GEORGIA AND HECATE STRAIT	21

1 INTRODUCTION

The Regional District of Comox-Strathcona (pop. 18,000) installed a 2750 metre-long marine sewage outfall off Cape Lazo, British Columbia in April 1984. Effluent was previously discharged directly into Comox Harbour (Figure 1).

The harbour was a valuable commercial source of oysters (Crassostrea gigas), until 1965, when it was closed to harvesting. This closure was the result of the 1964 bacteriological surveys by the Federal and Provincial Departments of Health. In 1974, the Environmental Protection Service (EPS) surveyed the Cape Lazo foreshore and harbour. As a result an additional portion of the Cape Lazo foreshore was closed, due to fecal contamination arizing from the CFB Comox Sewage Treatment Plant and adjacent agricultural run-off.

The new marine outfall off Cape Lazo consolidates the CFB Comox effluent, with effluents from the towns of Courtenay and Comox. This removes potential sources of fecal contamination from valuable commercial shellfish areas, to offshore areas which can more readily assimilate the nutrients, and where the fecal bacteria will not contaminate valuable oyster grounds. The Cape Lazo outfall ends in a 121 port diffuser, at a depth of about 60 m, in the Strait of Georgia (Figure 1). The effluent receives secondary treatment, undergoing screening, grit removal, primary settling, biological activated sludge treatment and clarification prior to discharge. The maximum permitted discharge from the outfall is 18,000 cu. metres per day. Discharge averaged about 8,000 cu. m per day, (April, May and June) and a total of about 400,000 cu. m were discharged through the outfall before we sampled the area in June 1984.

The present report compares 1979 baseline information (Holman et al. 1981), to data collected on 11 June 84, about two months after the outfall was gradually phased into operation. Our objective was to determine the impact of the discharge upon the physical and chemical characteristics of the water column and benthic environments.

1.1 Study Area (Figure 1)

Cape Lazo (49°41'53"N, 124°51'37"W), on the east side of Vancouver Island, is about 130 km northwest of Vancouver. It is surrounded by waters of the Strait of Georgia, the most important marine region of British Columbia, in terms of a multiple-use resource (Thomson 1981).

Various review articles have summarized environmental information on the Strait of Georgia:

fisheries (Ketchen, Bourne and Butler 1983)
oceanography (LeBlond 1983, Harrison et al. 1983, Thomson 1981, Tully and Dodimead 1957, Parsons et al. 1970, Herlinveaux and Giovando 1969)
benthos (Levings, Foreman and Tunnicliffe 1983, Bernard 1978)
pollution (Waldichuk 1983, Parsons 1972, Parsons et al. 1970, 1980, Ellis 1980)

1.1.1 Fisheries Resource. The Strait of Georgia is an important fisheries area: fisheries resources had a market value of 104 million dollars in 1980 (Ketchen et al. 1983). Several major stocks of Pacific salmon use the area for rearing and migration. However, herring (Clupea harengus pallasi) is the most valuable commercial species harvested. For the past 4 to 5 years about 12 million dollars worth of herring roe was harvested yearly in the Comox fishing sub-district.

Comox fisheries officer, L. Freeman, reports (pers. comm.) that grey cod, rock fish, and dogfish are locally important groundfish species. Prawn and shrimp trawling supports 10 to 12 boats off Cape Lazo between October and March and recently, divers have begun to harvest sea urchins (Strongylocentrotus droebachiensis) in January and February. Geoduck clams (Panope generosa) are also commercially fished by divers. In 1978 about 26% of all B.C. geoducks were harvested in this fishing district.

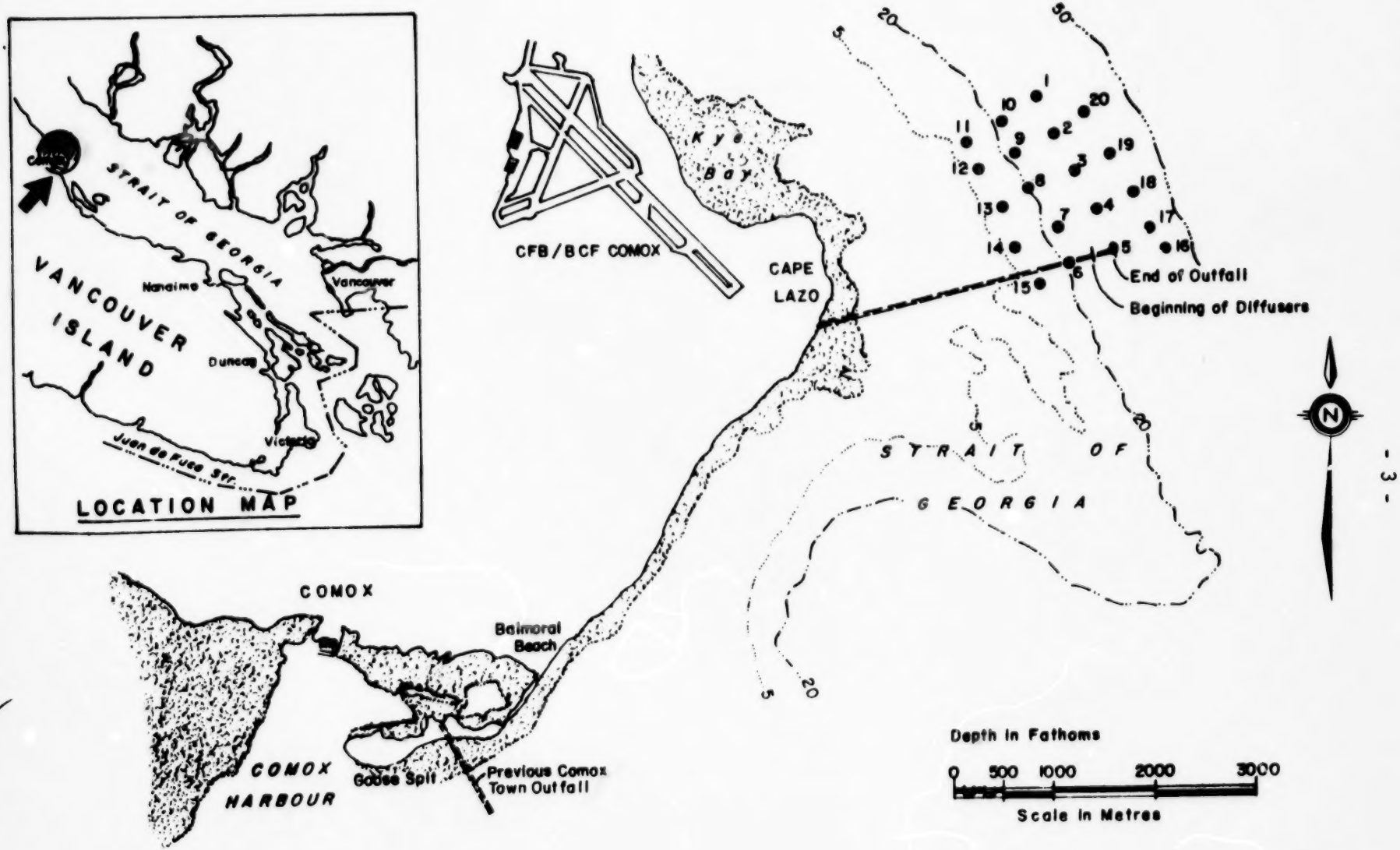

FIGURE 1 SURVEY AREA - November 6, 1979 and June 11, 1984

1.1.2 Oceanography. The mixed, mainly semidiurnal tides in the Strait of Georgia have a period of about 12 hours, 25 minutes. They generally increase in magnitude from south to north. At Cape Lazo mean tides have a range of 3.35 metres. Surface currents in the area are generally weak (10 cm/s, Waldie 1951; 31 cm/s, Anderson 1975) resulting in weak tidal mixing.

However, Dayton and Knight Ltd. 1979, report results from a current survey off Cape Lazo, in the vicinity of the outfall. In general, the net current movements, as determined by drougues, were in a north-south direction. Measured maximum current speeds were 46.1 cm/s (depth = 10 m) and 42.9 cm/s (24 m), while mean speed ranges were 3.6 - 12.5 cm/s (10 m) and 2.8 - 12.4 cm/s (24 m). In addition, the water column was only weakly stratified in October, and unstratified in January.

1.1.3 Benthos. Levings et al. (1983) considers depth and substrate to be important factors influencing benthic productivity in the Strait of Georgia. Shallow areas closer to the euphotic zone, and locales with rocky substrates, are areas that support richer communities than deeper basin zones, which have finer sediment substrates. Bernard (1978) also cites sediment particle size as a prime factor governing the distribution of benthic organisms.

The benthic substrate off Cape Lazo has been classified as generally coarse; sandy-gravel, sand, gravelly-sand or muddy-sand (Luternauer, Clague and Pharo 1983).

1.1.4 Pollution. Parsons et al. (1970) concluded that beyond local effects there was no apparent influence of pollution on the pelagic production of the Strait of Georgia.

In a later review of pollution in the Strait, Waldichuk (1983) concluded that the Strait of Georgia is relatively unpolluted, when taken as a whole. He states that this is largely due to the annual replacement of the shallow waters. This replacement is made possible by relatively

free connections with the open ocean, moderately large tidal range, and a large freshwater run-off which enters the Strait.

Local areas of the Strait are degraded by sources of pollution. Waldichuk (1983) cites sewage pollution and it's impact upon shellfish resources as a notable example. Many shellfish areas in the Strait of Georgia are closed due to high levels of fecal contamination. Some of this contamination is due to point sources like sewage outfalls, other areas are affected by agricultural run-off (Kay 1976) or by discharges from recreational vessels (Kay 1982).

Kay and Tevendale (1974) surveyed Comox Harbour and adjacent foreshore, and concluded that the Comox town sewage outfall (Figure 1) did not appreciably change the water quality inside or outside the harbour. This was indicated by coliform counts at a station immediately above the outfall, three stations across the harbour, and several stations outside the harbour. All these stations met shellfish growing water standards (U.S. Department of Health, Education and Welfare 1965) for fecal coliforms.

However, Kay and Tevendale (1974) did identify several sources of fecal contamination:

- Courtenay River through input of Tsolum River and its pasture land run-off
- Comox town sewage pumphouse during excessive flows or pump breakdowns
- Roy Creek and Trent River
- Ditch (station S10) which receives CFB Comox sewage treatment plant effluent and farmland run-off.

Kay (in prep.) surveyed the area in May 1984 and in February 1985. He will report the changes in harbour water quality in a future EPS publication now that CFB Comox and Comox-Courtenay town effluents are discharged through the new deep-water outfall off Cape Lazo.

TABLE 1 LIST OF SAMPLING STATIONS, DEPTHS, LOCATIONS AND SAMPLES TAKEN ON 11 JUNE 84

STATION		DISTANCE FROM OUTFALL (m)	RANK	LATITUDE (N)	LONGITUDE (W)	SEDIMENT			WATER		
CO	Depth (m)					BACT (1)	PS (2)	TM (3)	NUT (4)	DO (5)	CTD (6)
1	(73)	1764	1	49 43.1'	124 49.8'	X	X	X			
2	(59)	1344	5	49 42.9'	124 49.7'	X	X	X			
3	(64)	890	8	49 42.7'	124 49.5'	X	X	X	X	X	X
4	(64)	462	13	49 42.5'	124 49.35'	X	X	X	X	X	
5	(63)	122	15	49 42.3'	124 49.2'	X	X	X	X	X	X
6	(47)	332	14	49 42.2'	124 49.55'	X	X	X			
7	(43)	512	11	49 42.4'	124 49.65'	X	X	X			
8	(53)	1029	6	49 42.6'	124 49.9'	X	X	X			
9	(53)	1381	4	49 42.8'	124 50.0'	X	X	X			
10	(52)	1701	2	49 42.96'	124 50.08'	X	X	X			
16	(83)	634	10	49 42.3'	124 48.75'	X	X	X			
17	(80)	512	11	49 42.4'	124 48.92'	X	X	X			
18	(81)	693	9	49 42.6'	124 49.04'	X	X	X			
19	(83)	1029	6	49 42.8'	124 49.2'	X	X	X			
20	(81)	1449	3	49 43.01'	124 49.45'	X	X	X			

(1) Bacteria: Fecal Coliforms

(2) Particle Size, Oil and Grease, Total Volatile Residue

(3) Trace Metals: Cd, Cr, Cu, Mn, Ni, Pb, Zn, Fe, Al

(4) Nutrients: Nitrate, Nitrite, Ammonia, Total Phosphate

(5) Dissolved Oxygen

(6) CTD: Conductivity, Temperature, Depth (Salinity, Density)

2 METHODS

2.1 Survey Area (Figure 1)

The 1979 survey area consisted of 15 stations which covered about 2.6 km^2. When the area was sampled in 1984, after the Cape Lazo outfall was installed, 5 new stations were added to allow for future deep-water monitoring, while 5 inshore stations were discontinued. On 11 June 84, 15 stations (Table 1) were sampled from the C.S.S. Vector. Stations were located using ship's radar and LORAN-C system.

2.2 Sediments Samples

A 0.1 m^2 Smith-MacIntyre grab was used to collect sediment samples for bacteria, particle size, oil and grease, and trace metal analyses. The surficial sediment layer was collected using a plastic scoop, avoiding sediment near the sides of the grab. Samples were placed in paper sediment bags and immediately frozen. Bacterial samples were collected using previously sterilized spatulas and glass containers. Samples were kept cool prior to incubation, dilution, and evaluation at the EPS North Vancouver Bacteriology Lab. The technique described in Swingle and Davidson (1979) was followed except that samples were mixed by hand, instead of a blender (Kay; pers. comm.). Particle size, oil and grease and trace metals were analysed at the Environment Canada Lab in West Vancouver following the methods of Swingle and Davidson (1979). Oils and grease were extracted for 24 hours using hexane. Trace metal concentrations in sediment (passing a 100-mesh; 0.15 mm seive) were determined with an Inductively Coupled Argon Plasma (ICAP) excitation source connected to a Optical Emission Spectrophotometer (OES).

2.3 Water Samples

Water samples were collected using standard N.I.O. bottles from stations CO-3, 4, 5 when the tidal flow was northerly, so that the effluent plume could be more readily detected. Samples for nutrient analysis (total

phosphate, nitrate, nitrite, and ammonia) were immediately frozen (Strickland and Parsons 1971), then analysed by Environment Canada, West Vancouver Lab using an Automated Colorimeter (Technicon Auto-analyzer II) according to methods described in Swingle and Davidson (1979). Percent saturation was calculated using the equation outlined in Gameson and Robertson (1955). Two CTD profiles were taken at stations CO-3 and CO-5 using a Plessy Instruments Model 9400 CTD sensor as described by Goyette and Macleod (1984). These stations were selected due to their proximity to the outfall.

2.4 Data

Data analyses were done on a Hewlett-Packard 9826 computer with the HP STATISTICAL LIBRARY programmes (Dec. 1982 Edition) designed for HP 200 series computers. The least-squares multiple linear regression was used to obtain regression values for sediment parameters as a function of distance from the outfall. Stations were ranked according to their distance from the outfall: the nearest station ranked 15th., the most distant station ranked 1st. Thus, if a parameter like metal concentration was highest near the outfall, a positive relationship would exist with Distance (rank). Conversely, if metal levels were higher at more distant stations, then a negative relationship would exist with Distance (rank), although a positive relationship would exist with Distance (metres). Data from duplicate and replicate sediment samples were pooled prior to analysis. Significance values were obtained from Rohlf and Sokal (1969).

3 RESULTS AND DISCUSSION

3.1 Seawater Conditions

3.1.1 Temperature/Salinity/Density (Table 2, Figure 2 and Appendix I).

A stratified water column existed during the study period: the surface (0-15 m) layer was warmer, less saline and consequently less dense than the deeper 45 metres. No impact of the sewage outfall was detected upon these parameters.

3.1.2 Dissolved Oxygen (Table 2 and Figure 1). Dissolved oxygen was sampled at two stations (CO-3, CO-5) located 890 and 122 metres northwest of the outfall. Maximum oxygen concentrations were found in the top 10 metres where waters were supersaturated (122-144%; 9.95-12.65 mg/l) due to high phytoplankton productivity. Oxygen concentrations decreased to 66-69% saturation (6.1-6.4 mg/l) at 57 metres depth. These deeper-water concentrations are similar to values obtained in 1979 (Holman et al. 1981) before the outfall was installed. No impact of the sewage outfall was detected with respect to dissolved oxygen levels.

TABLE 2 STATIONS CO-3, CO-5: DEPTH, TEMPERATURE, SALINITY, OXYGEN CONCENTRATION AND PERCENT SATURATION ON 11 JUNE 1984

DEPTH (m)	TEMP (C)		SAL (ppt)		DO (mg/l)		% SATURATION	
	Station 3	Station 5	Station 3	Station 5	Station 3	Station 5	Station 3	Station 5
0	15.90	15.47	27.27	27.53	9.95	10.25	122.05	124.85
2	15.34	15.04	27.32	27.49	10.05	10.65	121.92	128.55
5	14.46	13.41	27.57	27.78	10.60	11.25	126.48	131.48
10	11.92	12.63	28.21	28.43	12.65	12.30	143.55	141.97
25	10.00	10.00	29.23	29.25	7.45	7.43	81.52	81.53
50	9.52	9.55	29.51	29.52	6.70	6.65	72.64	72.15
57	9.38	9.41	29.62	29.62	6.10	6.40	65.97	69.26

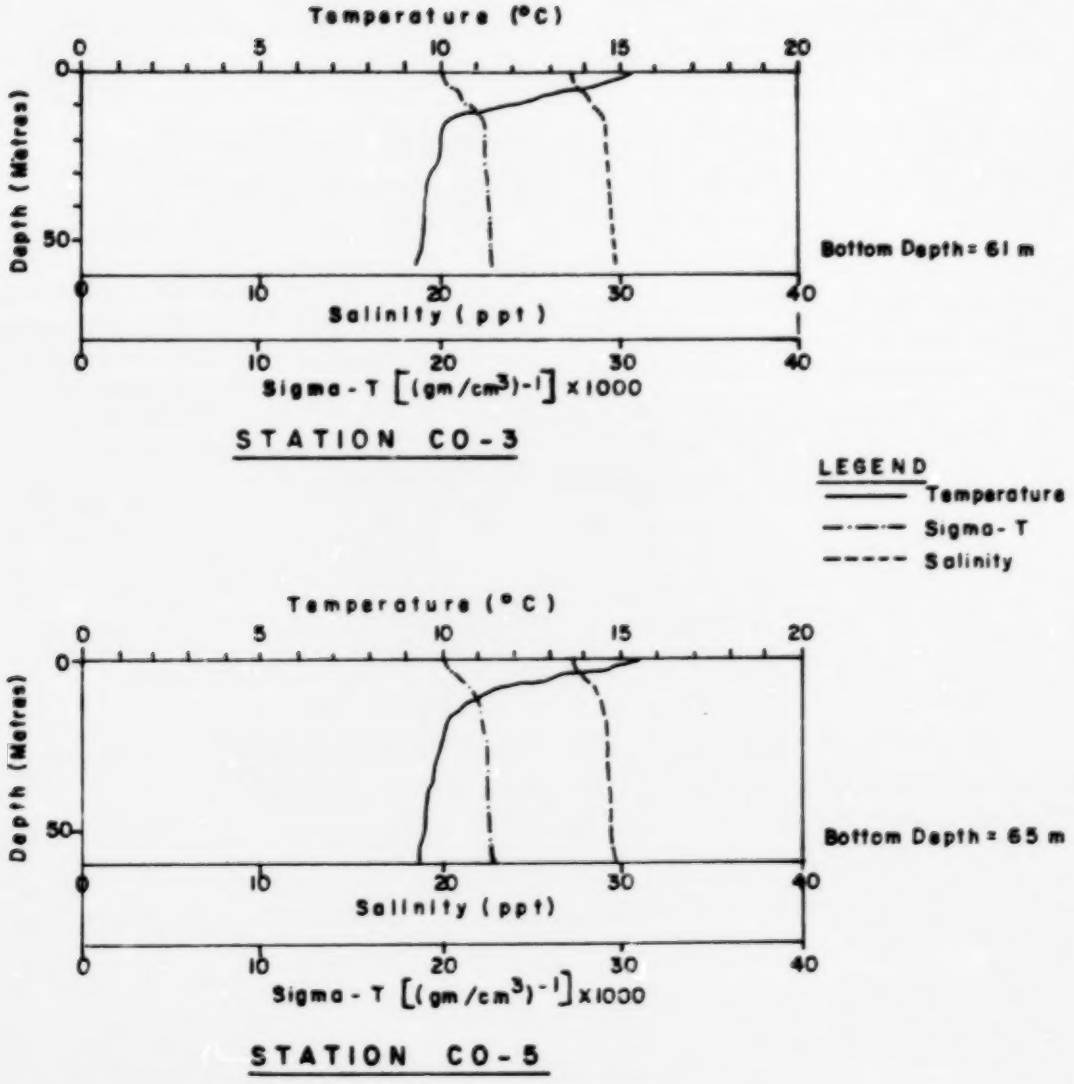

FIGURE 2 CTD PROFILES - STATIONS CO-3 AND CO-5 ON JUNE 11, 1984

3.1.3 Nutrients (Table 3). Nutrients were sampled at stations CO-3, 4, 5. All nutrients had low concentrations in the surface waters, due to the high summer primary productivity in the 0-10 m layer (Stephens et al. 1969). The generally low values of dissolved nutrients found, also agrees with the findings of Parsons et al. (1970). Compared to 1979 values, the only evidence of a sewage plume was increased ammonia concentration at depths of 25 metres or more. However, the maximum ammonia value (0.023 mg/l) found 890 m from the outfall at station CO-3 (25 m), is equivalent to less than 0.004 mg/l un-ionized ammonia (Emmerson et al. 1975). This is 1000-times less than the ammonia concentration of un-ionized ammonia (> 0.40 mg/l) which constitutes a hazard for marine life (Clark 1980). Similar pre-operational (Packman 1977) and post-operational (Pomeroy and Packman 1981) nutrient levels were found around the Five-Finger Island marine outfall near Nanaimo.

Although the influence of nutrients from sewage in an enclosed area can cause dramatic changes, their influence in more open marine areas (like Cape Lazo) is less significant (McIntyre and Johnston 1975).

3.2 Sediment Characteristics

3.2.1 Particle Size (Table 4 and Appendix II). Median particle sizes were determined graphically (Griffiths 1967). Median size - Modal size descriptions follow:

- Five stations most distant from the outfall (Figure CO-1, 2, 3, 9, 10) all had Medium Sand - Fine Sand substrates.
- Nine stations sampled had Fine Sand - Very Fine Sand substrates (Table 4).
- Station CO-8 had Coarse - Medium Sand.
- Sediment silt-clay content was correlated to depth (r = 0.79, Table 5).

TABLE 3 STATIONS CO-3, CO-4, CO-5: NUTRIENT DATA 1984

DEPTH (m)	TOTAL PHOSPHATE (mg/l)			NITRITE (mg/l)			NITRATE (mg/l)			AMMONIA (mg/l)		
	Station			Station			Station			Station		
	3	4	5	3	4	5	3	4	5	3	4	5
0	0.013	0.020	0.023	< 0.005	< 0.005	< 0.005	< 0.01	< 0.01	< 0.01	< .005	< .005	.008
2	.012	.021	.020	< 0.005	< 0.005	< 0.005	< 0.01	< 0.01	< 0.01	< .005	< .005	< .005
5	.020	.021	.017	< 0.005	< 0.005	< 0.005	< 0.01	< 0.01	< 0.01	< .005	< .005	< .005
10	.055	.035	.055	< 0.005	< 0.005	< 0.005	0.04	< 0.01	< 0.01	.005	< .005	< .005
25	.072	.064	.070	< 0.005	< 0.005	< 0.005	0.29	0.10	0.11	.023	.010	.013
50	.080	.077	.077	< 0.005	< 0.005	< 0.005	0.19	0.16	0.15	.006	.010	.010
60	.084	.077	.079	< 0.005	< 0.005	< 0.005	0.15	0.18	0.17	< .005	.009	.009

TABLE 4 SEDIMENT PARTICLE SIZE CHARACTERISTICS FOR STATIONS C01-20/84

STATION CO	MEDIAN PARTICLE		MODAL PARTICLE	% SILT CLAY	SORTING	
	Size (mm)	Type	Type		Coef.	Degree
1	0.27	Medium Sand	Fine Sand	4.5	1.33	Well
2	0.25	Medium Sand	Fine Sand	4.5	1.40	Well
3	0.30/ 0.35	Medium Sand	Fine Sand	3.4/ 2.9	1.32	Well
4	0.21/ .214	Fine Sand	Very Fine Sand	4.8/ 4.6	1.31	Well
5	0.214/ 0.214	Fine Sand	Fine Sand	6.7/ 5.5	1.37	Well
6	0.24	Fine Sand	Very Fine Sand	4.0	1.35	Well
7	0.25	Fine Sand	Fine Sand	3.7	1.41	Well
8	0.59	Coarse Sand	Medium Sand	0.4	1.41	Well
9	0.33	Medium Sand	Fine Sand	1.9	1.22	Well
10	0.38	Medium Sand	Fine Sand	1.2	1.29	Well
16	0.177	Fine Sand	Fine Sand	7.5	1.14	Well
17	0.214	Fine Sand	Very Fine Sand	6.6	1.14	Well
18	0.192	Fine Sand	Very Fine Sand	7.5	1.24	Well
19	0.214	Fine Sand	Very Fine Sand	7.2	1.35	Well
20	0.24	Fine Sand	Very Fine Sand	5.7	1.48	Well
x =	0.28	Medium Sand				

The average median particle size for the area was 0.28 mm (medium sand). Stations C016-20 located in deeper water, further offshore, had more Silt-Clay (6.9 ± 0.76%) compared to other stations (3.7 ± 1.75%). All sediment was well-sorted, having sorting coefficients less than 2.5 (Griffiths 1967). Similar results were obtained by Holman et al. (1981) in their initial survey of the area in 1979.

3.2.2 Organic Carbon (Tables 5 and 6). All stations sampled in June 1984 had higher total volatile residue values (21.6 to 44.6 mg/g) compared to (< 10 to 17 mg/g) for November 1979 stations (Table 6). However, it is not possible to conclude that the higher organic carbon values obtained in June 1984 were due to the effluent, or perhaps related to seasonal variation in organic carbon, until the area has been re-surveyed in a winter month. In fact, organic carbon values were negatively related with rank of distance from the outfall ($R = -0.51$) and not correlated with concentrations of oil and grease ($r = 0.27$, Table 5).

However, McIntyre and Johnston (1975) cite the example of high organic loading from a sewage outfall causing a six-fold increase in the input of carbon to the benthic sediments. Pomeroy (1982) also found a trend of increasing organic content of sediments near the French Creek outfall on Vancouver Island.

McNulty (1961) found zones devoid of life within 200 yards of sewage outfalls in addition to pronounced enriched zones in sandy-mud areas of Biscayne Bay which were shallow, and had good tidal circulation. He concluded that the high organic loading caused an inhibitory effect but that nutrients stimulated growth.

In summary, no impact on organic carbon levels could be linked to the new Cape Lazo outfall at this time. However, this parameter will obviously require further scrutiny during future monitoring surveys.

3.2.3 Oil and Grease (Tables 5 and 6). Oil and grease were not sampled in 1979. The 1984 values (Table 6) were highly variable between

stations (< 60 to 170 mg/kg), and within each station (eg. < 60 to 110 mg/kg at CO-4). No impact of the outfall was detected: oil and grease levels were not related with rank of distance from the outfall (r = 0.001, Table 5).

TABLE 5 CORRELATION MATRIX: % SILT AND CLAY, T.V.R., OIL AND GREASE, DEPTH, DISTANCE TO OUTFALL (rank) DISTANCE TO OUTFALL (metres)

	DIST (rank)	TVR (mg/g)	OIL (mg/kg)	DEPTH (m)	DIST (m)
SILT - CLAY %	.349	-.137	.142	.790*	-.397
DIST (rank)		-.511	.001	-.115	-.991#
TVR (mg/g)			.268	.340	.460
OIL (mg/kg)				-.032	-.007
DEPTH (m)					.043

*significant correlation ($p < 0.05$)

#An inverse relationship exists because Distance (metres) decreases as distance (rank) increases.

3.2.4 Bacteriology (Table 7). No coliform data was taken in 1979, however 1984 sediment bacteria data is presented in Table 7. Only four stations had detectable levels of fecal coliforms (20 to 70 fecal coliforms per 100 grams of sediment) based on the five tube dilution technique. These values merely indicate the presence of slight contamination (likely from the outfall). These levels do not indicate a hazard for human health: the standard for swimming water fecal coliforms is 200 per 100 ml of water.

TABLE 6 OIL AND GREASE AND TOTAL VOLATILE RESIDUE VALUES FOR STATIONS C01-10/79 AND C01-20/84

STATION	OIL AND GREASE (mg/kg)	TOTAL VOLATILE RESIDUE (mg/g)	
	1984	1984	1979
CO-1	81	35.3	11.
CO-2	170	38.0	10.
CO-3	< 60/92	42.5/28.6	11.
CO-4	< 60/110	30.2/28.7	13.
CO-5	87/60	32.0/28.8	17.
CO-6	90	21.6	10.
CO-7	110	22.5	< 10.
CO-8	110	44.6	< 10.
CO-9	< 60	30.3	< 10.
CO-10	< 60	28.8	< 10.
CO-16	66	30.5	-
CO-17	79	31.9	-
CO-18	110	31.7	-
CO-19	140	34.4	-
CO-20	66	36.9	-

TABLE 7 SEDIMENT FECAL COLIFORM DATA 1984

STATION	FECAL COLIFORMS/100 g SEDIMENT
CO-1	< 30
CO-2	< 20
CO-3	< 20
CO-4	< 20
CO-5	< 30
CO-6	< 30
CO-7	70
CO-8	< 20
CO-9	< 20
CO-10	< 20
CO-16	20
CO-17	50
CO-18	< 20
CO-19	20
CO-20	< 20

TABLE 8 MEAN VALUES OF METAL CONCENTRATIONS (mg/kg dry wt.) AT STATIONS CO1-10, 1979/84

METAL	MEAN + S.D. (CO 1-10/1979)	MEAN + S.D. (CO 1-10/1984)
Mercury (Hg)	0.165 ± 0.065	-------
Cadmium (Cd)	1.213 ± 0.022	0.363 ± 0.063
Chromium (Cr)	17.830 ± 1.656	22.618 ± 4.121
Copper (Cu)	12.014 ± 2.232	11.896 ± 1.766
Manganese (Mn)	245.200 ± 36.304	299.050 ± 58.233
Nickel (Ni)	9.702 ± 0.173	6.700 ± 1.438
Lead (Pb)	9.702 ± 0.173	3.045 ± 0.142
Zinc (Zn)	23.060 ± 6.633	27.125 ± 7.636
Aluminum(Al) (%)	-------	1.053 ± 0.115
Iron (Fe)(%)	2.054 ± 0.259	2.237 ± 0.406

*Indicates a significant increase ($p < 0.05$) between 1979 and 1984 values based on a 2 way ANOVA

3.2.5 Metal Concentrations (Tables 8-11 and Appendices 3-5).

Sediment metal concentrations were analysed in 1979 and 1984. Only data from stations sampled both years (C01-10) has been compared, however data from all stations (1979, 1984) are presented in Appendix III. Values were calculated using the observed concentrations or the detection limit value. Replicate and duplicate sample values (Appendix IV) were pooled to obtain a mean value. Field replication of samples showed a large mean difference between samples (9.4%-36.7%). These values are not surprising given the heterogeneity of benthic sediments and inevitable sampling errors caused by re-positioning the ship between samples. The largest differences in the field replicates were found with aluminum values. Aluminum was also the most variable metal in the lab duplicates. Mean values were used to lessen the variability of the data. Lab splitting of sediment samples produced a mean difference of (2.1%-18.0%).

Table 8 presents mean metal concentrations from stations C01-10 for 1979 and 1984. Since concentrations of mercury, cadmium, nickel, and lead were all at, or near their detection limits, no statistical analysis of these metals is possible.

Manganese, chromium, copper, zinc and iron values (Table 8) were subjected to a two-way analysis of variance (ANOVA) to determine if there were significant changes in metal concentrations between 1979 and 1984. Multiple linear regression analysis of 1984 data was used to examine metal concentration in relation to proximity to the outfall. Only manganese and chromium increased significantly ($p < 0.05$) between 1979 and 1984. However, these increases may not be due to the new outfall because:

- maximum and minimum values for both metals occured in the same general area before and after the outfall was installed (Table 9, Figure 3)
- values for Mn and Cr were not related to rank of distance from the outfall ($R = -0.47$, $R = -0.38$, Table 10) nor were any other metals (Appendix V)*.

*Similarly no relationship exists between metals and distance (m).

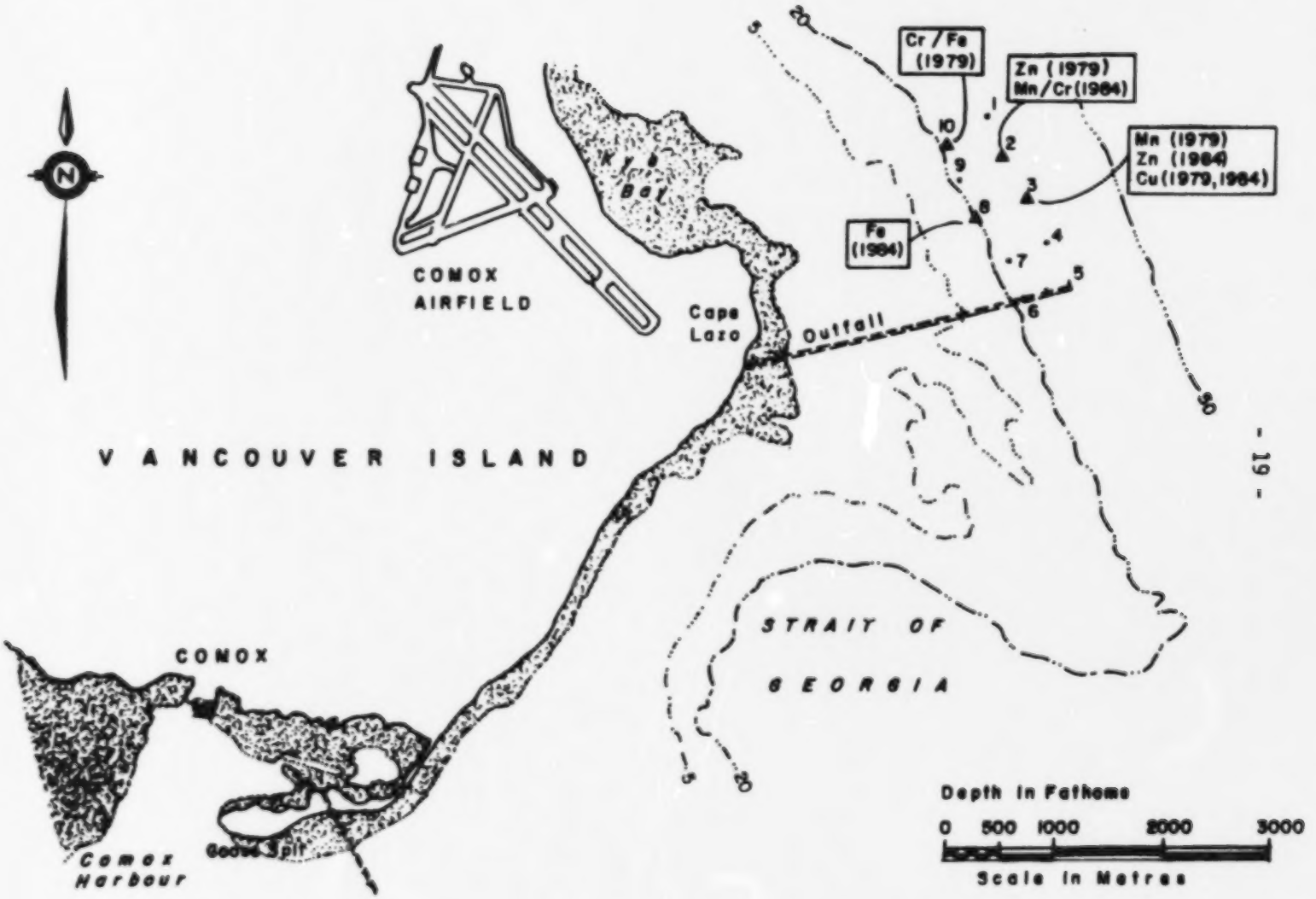
Cr / Fe (1979)
Zn (1979) Mn / Cr (1984)
Mn (1979) Zn (1984) Cu (1979, 1984)
Fe (1984)
COMOX AIRFIELD
Cape Lazo
Outfall
V A N C O U V E R I S L A N D
COMOX
Comox Harbour
STRAIT OF GEORGIA
Depth in Fathoms
0 500 1000 2000 3000
Scale in Metres

FIGURE 3 LOCATION OF MAXIMUM SEDIMENT METAL VALUES AT STATIONS 1-10 DURING 1979 AND 1984

TABLE 9 STATION LOCATIONS OF MAXIMUM AND MINIMUM DATA VALUES AND DISTANCE TO OUTFALL FOR SEDIMENT METALS 1979 AND 1984 (Data from Appendix 3, Stations 1-10)

METAL	MAXIMUM				MINIMUM			
	1979		1984		1979		1984	
	Station	Dist. (m)	Station	Dist. (m)	Station	Dist. (m)	Station	Dist. (m)
Cr	10	1701	2	1344	9	1381	4	462
Mn	3	890	2	1344	9	1381	7	512
Cu	3	890	3	890	9	1381	6	332
Zn	2	1344	3	890	9	1381	6	332
Fe	10	1701	8	1029	5	122	5	122

Increases in copper, zinc and iron between 1979-1984 were not statistically significant and were also not related to distance from the outfall. No metal concentrations increased with increasing proximity to the outfall, and iron ($R = -0.53$), zinc ($R = -0.45$) actually decreased. This apparent decrease is due to the pre-discharge distribution of the metal. However, some metals are significantly correlated with depth of the station and the % silt-clay in the sediment (Table 10).

When mean sediment metal concentrations obtained at Cape Lazo are compared to data from other Strait of Georgia and Hecate Strait sites, it is apparent that Cape Lazo values fall within the range of values from other locations (Table 11).

TABLE 10 SEDIMENT METAL CONCENTRATIONS AND THEIR MULTIPLE REGRESSION COEFFICIENTS (R) AND CORRELATION COEFFICIENTS (r) WITH DISTANCE (rank) FROM THE OUTFALL, DEPTH, AND % SILT AND CLAY: STATIONS C01-20/84 (Data from Appendix 3)

METAL	DISTANCE (from outfall) (R)#	DEPTH (r)	SILT AND CLAY (r)
Cr	-0.380	-0.390	-0.481
Mn	-0.467	0.156	0.078
Cu	-0.109	0.904*	0.704*
Zn	-0.453	0.738*	0.327
Fe	-0.530	-0.570*	-0.908*
Al	-0.269	0.873*	0.690*

#These negative values demonstrate that sediment metal values do not increase as the outfall is approached. In fact, all metals have varying degrees of a negative relationship with distance to the outfall. This reflects the distribution of sediment metal levels as they were before the installation of the outfall, mainly lower near the outfall, and higher at more distant stations. Values are non-significant ($p > 0.05$).

*Indicates significant correlation ($p < 0.05$).

TABLE 11 SEDIMENT METALS: MEAN VALUES OR RANGE IN MEAN VALUES FOR SELECTED STATIONS IN THE STRAIT OF GEORGIA AND HECATE STRAIT

METAL*	STRAIT OF GEORGIA				HECATE STRAIT
	C01-10 1979	C01-20 1984	PACKMAN 1977	WALDICHUK 1983	SNEDDON AND HOLMAN 1982
Cr	17.83	22.62	-	------	12.44 - 22.52
Cu	12.01	11.90	393.46	37.8 - 91.4	3.51 - 7.42
Mn	245.20	299.05	66.29	------	187.33 - 334.14
Zn	23.06	27.12	2.28	91.4 - 102.3	15.99 - 32.20
Fe (%)	2.05	2.24	-	2.78 - 3.40	1.66 - 3.99
Al (%)	--	1.05	-	------	0.69 - 0.97

*Concentrations are mg/kg (dry wt.) except for Fe and Al which are (%) dry wt.

Metal concentrations in sediment will continue to be monitored in the future since a significant increase of manganese and iron were found following the installation of a deep-sea outfall at French Creek, north of Nanaimo, on Vancouver Island (Pomeroy 1982). Although data on chromium was not available, Pomeroy (1982) also found slightly increased levels of copper and nickel. Soulsby et al. (1978) reported elevated chromium levels (25 mg/kg) near a sewage outfall, compared to other areas (9-13 mg/kg) in Portsmouth Harbour, England. They also found that levels of copper, lead, zinc, and cadmium were double the values found further away from the discharge area. Manganese and nickel were least concentrated nearest the outfall where estuarine conditions may have influenced their concentrations.

3.3 Summary

1. Data obtained in June 1984, several months after discharge began, are compared to 1979 results.

2. No impact of the sewage outfall was detected on seawater concentrations of nitrite, nitrate, and total phosphate. A slight increase in ammonia levels was detected, although the equivalent un-ionized concentration of ammonia (0.0004 mg/l) is 1000-times less than levels considered hazardous to marine life (Clark 1980).

3. There was no detectable impact of the outfall on sediment particle size distribution.

4. Although sediment organic carbon levels (TVR) increased between 1979 and 1984 (< 10-17 mg/g to 21.6-44.6 mg/g), seasonal variation may be a factor in the increase, especially since TVR was negatively related to distance from the outfall ($R = -0.51$) and was not significantly correlated with concentrations of oil and grease ($r = 0.27$, Table 5).

5. Bacterial levels in sediments from two stations near the outfall showed low-level fecal contamination (50-70 MPN/100 g), while levels at all other stations were below the detection limits (< 20-< 30 MPN/100 g).

6. Although Mn and Cr increased significantly between 1979 and 1984, their increases are not attributable to the outfall because:

   a) All sediment metal concentrations were negatively related (R = -0.11 to -0.53) to proximity of the outfall: metal concentrations decreased nearer the outfall, and increased further away.

   b) Maximum and minimum metal concentrations occured in the same general area before and after the outfall was installed.

8. Monitoring at Cape Lazo will be continued due to the diverse fisheries resources of the area.

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APPENDIX I

CTD DATA 11 JUNE 84 STATIONS CO-3 AND CO-5

APPENDIX I CTD DATA 11 JUNE 84 STATIONS CO-3 AND CO-5

Survey Area: CAPE LAZO
Station: CO-3
Latitude: 49 42 7
Longitude: 124 49 5
Date: 84/06/11

Time (start cast): 1802 PDT
Time (stop cast): 1806 PDT

Depth Reading in Air: 1.40 meters
Bottom Depth (sounder): 61.00 meters

DEPTH (m)	TEMPERATURE (°C)	SIGMA-T	CONDUCTIVITY (umhos/cm)	SALINITY (ppt)
0.0	15.90	19.83	34.9827	27.2646
1.0	15.83	19.85	34.9463	27.2782
2.0	15.34	19.99	34.6069	27.3205
3.0	15.09	20.10	34.4940	27.3998
4.0	14.77	20.24	34.3477	27.4921
5.0	14.53	20.35	34.2445	27.5677
10.0	12.63	21.20	33.4286	28.2071
15.0	10.38	22.26	32.5080	29.0613
20.0	10.03	22.43	32.3862	29.2143
25.0	10.00	22.45	32.3808	29.2312
30.0	9.81	22.54	32.2982	29.3008
35.0	9.62	22.65	32.2521	29.4039
40.0	9.57	22.70	32.2707	29.4625
45.0	9.56	22.73	32.2965	29.4988
50.0	9.52	22.75	32.2862	29.5133
56.9	9.38	22.85	32.2730	29.6198

CONTINUED...

APPENDIX I CTD DATA 11 JUNE 84 STATIONS CO-3 AND CO-5
(Continued)

Survey Area: CAPE LAZO
Station: CO-5
Latitude: 49 42 3
Longitude: 124 49 5
Date: 84/06/11

Time (start cast): 1946 PDT
Time (stop cast): 1950 PDT

Depth Reading in Air: .90 meters
Bottom Depth (sounder): 65.00 meters

DEPTH (m)	TEMPERATURE (°C)	SIGMA-T	CONDUCTIVITY (umhos/cm)	SALINITY (ppt)
0.0	15.47	20.12	34.9414	27.5262
1.0	15.42	20.11	34.8670	27.4961
2.0	15.04	20.18	34.5594	27.4911
3.0	14.72	20.30	34.3770	27.5520
4.0	14.50	20.34	34.1980	27.5486
5.0	13.50	20.71	33.6570	27.7769
10.0	11.92	21.50	33.0892	28.4280
15.0	10.52	22.16	32.5234	28.9586
20.0	10.12	22.38	32.4042	29.1629
25.0	10.00	22.47	32.3983	29.2512
30.0	9.89	22.53	32.3705	29.3048
35.0	9.80	22.59	32.3542	29.3634
40.0	9.64	22.66	32.2834	29.4194
45.0	9.57	22.72	32.2966	29.4853
50.0	9.55	22.74	32.3100	29.5167
56.7	9.41	22.85	32.3036	29.6193

APPENDIX II

SEDIMENT PARTICLE SIZE DISTRIBUTION (%) STATIONS CO1-20/84

APPENDIX II SEDIMENT PARTICLE SIZE DISTRIBUTION (%) STATIONS CO1-20/84

STATION	SILT & CLAY < 0.063 mm	VERY FINE SAND < 0.125 mm	FINE SAND < 0.250 mm	MEDIUM SAND < 0.50 mm	COARSE SAND < 1.0 mm	VERY COARSE SAND < 2.0 mm	GRANULES > 2.0 mm
CO-1	4.5	32.5	55.6	6.0	0.7	0.3	0.4
CO-2	4.5	35.8	51.0	7.2	1.0	0.3	0.2
CO-3	3.4/2.9	23.3/31.5	47.4/56.6	12.7/7.9	2.8/0.8	0.5/0.1	9.9/0
CO-4	4.8/4.6	51.9/46.6	39.0/45.2	3.5/2.7	0.4/0.4	0.3/0.2	0.1/0.2
CO-5	6.7/5.5	62.5/60.8	28.0/29.7	1.8/2.8	0.4/0.5	0.4/0.4	0.2/0.2
CO-6	4.0	48.2	43.3	1.5	1.0	0.7	1.1
CO-7	3.7	45.5	47.6	2.4	0.5	0.1	0.2
CO-8	0.4	2.4	23.7	58.6	14.4	0.4	0.1
CO-9	1.9	18.4	69.1	9.6	0.8	0.1	0.1
CO-10	1.2	12.5	59.1	24.1	2.8	0.1	0.1
CO-16	7.5	66.6	22.1	3.2	0.4	0.2	0.1
CO-17	6.6	63.5	28.1	0.7	0.5	0.4	0.2
CO-18	7.5	66.7	22.4	2.9	0.3	0.3	0.0
CO-19	7.2	62.6	26.9	2.7	0.3	0.2	0.1
CO-20	5.7	48.5	41.4	3.7	0.4	0.2	0.0

APPENDIX III

SEDIMENT DATA 1979 AND 1984

APPENDIX III SEDIMENT DATA 1979-1984

STATION		SILT AND CLAY (%)	Al (%)	DISTANCE (rank)	TVR (mg/g)	OIL (mg/kg)	DEPTH (m)	DISTANCE (m)
1979	1	14.20	-	-	11.0	-	58	-
	2	3.20	-	-	10.0	-	58	-
	3	2.30	-	-	11.0	-	64	-
	4	4.30	-	-	13.0	-	59	-
	5	3.70	-	-	17.0	-	68	-
	6	3.40	-	-	10.0	-	48	-
	7	1.40	-	-	10.0	-	44	-
	8	1.60	-	-	10.0	-	53	-
	9	1.00	-	-	10.0	-	53	-
	10	1.20	-	-	10.0	-	55	-
	11	0.00	-	-	10.0	-	20	-
	12	0.00	-	-	10.0	-	14	-
	13	0.10	-	-	10.0	-	13	-
	14	0.00	-	-	10.0	-	16	-
	15	0.60	-	-	10.0	-	18	-
1984	1	4.50	1.20	1	35.3	81.0	73	1764
	2	4.50	1.21	5	38.0	170.0	59	1344
	3	3.15	1.16	8	35.5	76.0	64	890
	4	4.70	1.13	13	29.5	85.0	64	462
	5	6.10	1.02	15	30.4	73.5	63	122
	6	4.00	0.90	14	21.6	90.0	47	332
	7	3.70	0.94	11	22.5	110.0	43	512
	8	0.40	0.93	6	44.6	110.0	53	1029
	9	1.90	1.04	4	30.3	60.0	53	1381
	10	1.20	1.00	2	28.8	60.0	52	1701
	16	7.50	1.30	10	30.5	66.0	83	634
	17	6.60	1.15	11	31.9	79.0	80	512
	18	7.50	1.23	9	31.7	110.0	81	693
	19	7.20	1.23	6	34.4	140.0	83	1029
	20	5.70	1.21	3	36.9	66.0	81	1449

APPENDIX III SEDIMENT DATA 1979 AND 1984

STATION	Hg (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Mn (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Fe (%)
1979 1	.161	1.230	18.70	13.60	296.0	9.85	9.85	20.70	2.02
2	.098	1.240	18.40	14.40	241.0	9.91	9.91	39.60	2.11
3	.166	1.240	20.30	14.90	322.0	9.89	9.89	28.50	2.39
4	.099	1.180	16.40	12.00	239.0	9.44	9.44	20.20	1.85
5	.271	1.190	17.00	14.50	228.0	9.49	9.49	23.00	1.79
6	.164	1.210	16.30	10.80	214.0	9.72	9.72	17.90	1.86
7	.102	1.190	17.30	9.95	220.0	9.54	9.54	21.00	2.05
8	.216	1.220	18.20	10.40	239.0	9.79	9.79	20.30	2.08
9	.186	1.200	15.40	8.39	208.0	9.59	9.59	16.70	1.81
10	.190	1.230	20.30	11.20	245.0	9.80	9.80	22.70	2.58
11	.096	1.190	40.80	11.30	263.0	9.57	10.20	17.50	5.65
12	.100	1.220	53.0	11.80	349.0	9.76	10.50	16.40	6.78
13	.099	1.200	25.00	9.01	281.0	9.56	9.56	20.70	3.52
14	.097	1.230	26.70	9.97	291.0	9.84	9.84	24.20	3.89
15	.097	1.230	17.70	8.51	240.0	9.69	9.69	14.90	2.31
1984 1	-	.300	21.60	14.10	319.0	9.00	3.00	33.40	2.10
2	-	.350	32.30	13.15	424.0	7.00	3.00	33.25	2.31
3	-	.300	22.75	14.85	362.0	7.50	3.00	33.60	2.32
4	-	.330	18.73	12.76	282.0	8.00	3.00	30.90	1.94
5	-	.350	18.95	12.05	248.0	6.50	3.00	27.55	1.67
6	-	.300	21.70	9.80	249.0	8.00	3.00	13.30	1.84
7	-	.500	18.60	10.30	243.0	6.00	3.00	13.70	1.99
8	-	.395	26.15	11.15	320.5	5.00	3.45	27.15	2.96
9	-	.400	22.70	10.70	268.0	5.00	3.00	31.60	2.68
10	-	.400	22.70	10.10	275.0	5.00	3.00	26.80	2.55
16	-	.400	19.10	15.00	302.0	9.00	3.00	33.30	1.68
17	-	.600	17.30	14.10	260.0	9.00	3.00	31.50	1.70
18	-	.300	21.60	14.85	288.0	10.00	3.00	32.60	1.80
19	-	.400	18.10	14.70	301.0	10.00	3.00	35.30	1.78
20	-	.300	18.50	14.00	306.0	8.00	3.00	32.60	1.82

APPENDIX IV

SEDIMENT FIELD REPLICATE AND LABS DUPLICATE SEDIMENT DATA 1984

APPENDIX IV SEDIMENT FIELD REPLICATE AND LAB DUPLICATE SEDIMENT DATA 1984

STATION	ELEMENT OR CONSTITUENT	FIELD VALUE	FIELD REPLICATE	LAB DUPLICATE	% DIFFERENCE	
					Field	Lab
CO-2	Cr	21.2	-	22.2	-	4.7
3	(mg/kg)	24.3	21.2	-	12.7	-
4		18.1	19.2	18.9	6.1	1.5
5		18.7	14.5	-	22.4	-
8		25.9	-	26.4	-	1.9
18		18.0	-	25.2		40.0
				$\bar{x}$	13.7	12.0
CO-2	Cu	13.0	-	13.3	-	2.3
3	(mg/kg)	16.7	13.0	-	22.1	-
4		13.2	12.4	12.7	6.0	2.4
5		14.0	10.1	-	27.8	-
8		10.7	-	11.6	-	8.4
18		14.8	-	14.9	-	0.7
				$\bar{x}$	18.6	3.5
CO-2	Mn	424.0	-	-	-	0
3	(mg/kg)	397.0	327.0	13.0	17.6	-
4		281.0	296.0	12.4	5.3	9.1
5		265.0	231.0	10.1	12.8	-
8		305.0	-	-	-	10.1
18		276.0	-	-	-	8.6
				$\bar{x}$	11.9	9.3
CO-2	Zn	32.9	-	33.6	-	2.1
3	(mg/kg)	35.9	31.3	-	12.8	-
4		31.8	31.1	29.8	2.2	4.1
5		31.1	24.0	-	22.8	-
8		27.0	-	27.3	-	1.1
18		32.4	-	32.8	-	1.2
				$\bar{x}$	12.6	2.1

CONTINUED...

APPENDIX IV SEDIMENT FIELD REPLICATE AND LAB DUPLICATE SEDIMENT DATA 1984 (Continued)

STATION	ELEMENT OR CONSTITUENT	FIELD VALUE	FIELD REPLICATE	LAB DUPLICATE	% DIFFERENCE	
					Field	Lab
CO-2	Fe	2.30	-	2.32	-	0.9
3	(%)	2.35	2.30	-	2.1	-
4		1.92	2.01	1.90	4.7	5.5
5		1.87	1.47	-	21.4	-
8		3.01	-	2.92	-	3.0
18		1.76	-	1.84		4.5
				$\bar{x}$	9.4	3.5
CO-2	Al	1.21	-	1.21	-	0.0
3	(%)	1.26	2.30	-	45.2	-
4		1.20	2.01	1.90	40.3	36.8
5		1.11	1.47	-	24.5	-
8		0.89	-	0.97	-	8.2
18		1.17	-	1.28	-	8.5
				$\bar{x}$	36.7	18.0
CO-2	TVR	38.0	-	-	-	-
3	(mg/g)	42.5	28.6	-	32.7	-
4		30.2	28.7	-	4.9	-
5		32.0	28.8	-	10.0	-
8						
18						
				$\bar{x}$	15.8	—
CO-2	Oil & Grease	170	-	-	-	-
3	(mg/kg)	92	< 60	-	35	-
4		110	< 60	-	46	-
5		86	< 60	-	30	-
8		-	-	-	-	
18		-	-	-	-	
				$\bar{x}$	37	—

APPENDIX V

CORRELATION MATRIX SEDIMENT DATA

APPENDIX V CORRELATION MATRIX SEDIMENT DATA 1984

	Cu (ppm)	Mn (ppm)	Zn (ppm)	Fe (%)	SILT & CLAY (%)	Al (%)	DISTANCE (rank)	TVR (mg/g)	OIL (mg/kg)	DEPTH (m)	DISTANCE (m)
Cr (ppm)	-.182	.740	.084	.650	-.482	-.086	-.381	.447	.517	-.390	.412
Cu (ppm)		.438	.777	-.456	.704	.924	-.107	.433	.121	.904	.040
Mn (ppm)			.534	.326	-.078	.482	-.467	.684	.522	.157	.464
Zn (ppm)				.002	.327	.819	-.453	.663	.021	.738	.408
Fe (%)					-.908	-.420	-.530	.429	.031	-.570	.546
Silt & Clay (%)						.690	.349	-.137	.142	.790	-.397
Al (%)							-.268	.350	.130	.873	.221
Distance (rank)								-.511	.001	-.115	-.990
TVR (mg/g)									.268	.340	.460
Oil (mg/kg)										-.032	-.007
Depth (m)											.043